EVALUATION OF EFFECTIVENESS PARAMETERS ON GAS DEHYDRATION PLANT

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor of Chemical Engineering (Gas Technology).

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ABSTRACT

Dehydration of Natural Gas to controlled water content is necessary in order to avoid gas hydrates and minimize corrosion. This study describes the dehydration on liquid desiccant dehydration unit. The key task was to identify the optimum parameters used in Triethylene Glycol dehydration unit. Absorption dehydration involves the use of Triethylene Glycol to remove water vapor from the gas stream. Water was removed to meet a water dew point requirement of sale gas contract specification range from 32.8 to 117 kg/10^6 standard m^3. The evaluation of effectiveness parameters on gas dehydration plant was carried out by using ASPEN HYSYS simulation. ASPEN HYSYS was used for steady state simulation, design, performance monitoring and optimization of oil and gas production, gas processing and petroleum refining industries. Peng-Robinson equation of state was chosen in the system. The simulation was carried out to determine the effect of important parameters such as column operating pressure, number of theoretical stages of column and gas flow rate. A technically optimized dehydration process has been proposed based on the simulated data. Results showed that, when the gas flow rate increases, the water absorption rate will decrease. Same condition obtained as increasing pressure. However, water absorption rate increases with the increasing number of theoretical stages. The optimum condition of gas dehydration was at 2000kPa with 1000m^3/h gas flow rate and 4 column theoretical stages.

Key words: Dehydration, hydrates, Triethylene Glycol, Aspen Hysys, absorption, optimization.

ABSTRAK

Penyahhidratan gas asli kepada kandungan air yang terkawal adalah diperlukan untuk mengelakkan pembentukkan hidrat gas dan meminimumkan pengaratan. Kajian ini telah menerangkan pengyahhidratan dengan menggunakan bahan pengering cecair dalam unit pengyahhidratan. Tujuan utama kajian ini adalah untuk mengenal pasti parameter optimum yang digunakan dalam unit pengyahhidratan yang menggunakan Triethylene Glycol. Penyahhidratan penyerapan melibatkan penggunaan Triethylene Glycol untuk memisahkan wap air dari aliran gas. Wap air dipisah untuk memenuhi keperluan titik embun air yang ditetapkan oleh specifikasi kontrak jualan gas yang merangkai dari 32.8 ke 117 kg/10^6 standard m^3. Penilaian parameter yang keberkesanan pada unit penyahhidratan dilaksanakan dengan menggunakan simulasi ASPEN HYSYS. Biasanya, ASPEN HYSYS digunakan dalam keadaan simulasi yang stabil, reka bentuk, pemantauan penampilan, dan pengoptimuman pengeluaran minyak dan gas ,serta industry pemprosesan gas dan penapisan petroleum. Persamaan Peng-Robinson adalah dipilih dalam sistem ini. Simulasi ini dijalankan untuk menentukan kesan-kesan parameter penting seperti tekanan operasi kolum, bilangan dulang kolum, dan kadar aliran gas. Process penyahhidratan yang dioptimumkan secara teknikal telah dicadangkan berdasarkan data-data simulasi. Sebagai keputusan, semasa kadar aliran gas meningkat, kadar penyerapan air akan menurun. Keadaan yang sama berlaku jika tekanan kolum meningkat. Akan tetapi, kadar penyerapan air akan meningkat dengan pertambahan bilangan dulang kolum. Keadaan penyahhidratan gas yang optimum berlaku pada 2000kPa dengan 1000m^3/h kadar aliran gas dan 4 dulang kolum.

Kata kunci: Penyahhidratan, hidrat, Triethylene Glycol, Aspen Hysys, penyerapan, pengoptimuman.

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LIST OF SYMBOLS

W_r	Water removed
W_i	Water content of inlet gas
W_o	Water content of outlet gas
Q_G	Gas flow rate
L	Liquid molar flow rate
X	Mole fraction in liquid phase
F	Feed molar flow rate
l	Refers to liquid phase
K	Equilibrium constant
$\bar{H}_i$	Fractional molar enthalpy of component I in liquid phase
H_i^+	Fractional molar enthalpy of component i in ideal gas state
φ_i^v	Fugacity coefficient of gas phase
γ_i	Activity coefficient
P	Pressure
V	Molar volume
T	Temperature
R	Universal gas constant (8.314 $J.K^{-1}.mol^{-1}$)
T_c	Critical temperature
P_c	Critical pressure
α	Alpha function, function of reduced temperature

LIST OF ABBREVIATIONS

CO_2	Carbon dioxide
H_2S	Hydrogen sulfide
TEG	Triethylene Glycol
SI	International System of unit
PFD	Process Flow Diagram
BTEX	Emission of Aromatic, e.g. Benzene, toluene, ethylbenzene, xylenes
VOC	Volatile Organic Compounds

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CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

1.1 BACKGROUND OF STUDY

Gas dehydration is widely used in natural gas treatment plant as a common process and it removes water that is associated with natural gases in vapor form. The natural gas industry has recognized that dehydration is necessary to ensure smooth operation of gas transmission lines as water and hydrocarbon can form gas hydrates which may block valves and pipelines.

Several methods have been developed to dehydrate gases on an industrial scale. The three major methods of dehydration are direct cooling, absorption of water in glycol, and adsorption of water by solid. In absorption processes, the absorption/stripping cycle is used for removing large amounts of water, and adsorption is used for cryogenic systems to reach low moisture contents and does not involve any chemical reaction. For commercial dehydration purpose, high absorption efficiency, and easy and economic regeneration should be possessed by those dehydrating agent. They should be non-corrosive and non-toxic, no operation problems when used in high concentration, no interaction with the hydrocarbon portion of the gas, and no contamination by acid gases.

When optimizing the design of dehydration facilities, the impact of number of trays in the contactor, liquid desiccant circulation rate through the contactor, temperature of the reboiler in the regenerator, amount of stripping gas used, and operating pressure of the regenerator should be considered.

1.2 PROBLEM STATEMENT

Natural gas is a mixture of many components which is classified into 3 major groups, that is hydrocarbons containing Hydrogen and Carbon, inert elements and trace compounds. Natural gas hydrates are solids that formed from natural gas hydrocarbons and water. The water molecules have a honeycomb structure with a molecule of one of the natural gas components occupying each void. Since these solids are denser than water ice, their formation is favored at higher pressure. Natural gas hydrates may form and interfere with the passage of natural gas through valves and pipes. These may block pipeline flow and control systems. Natural gas in transit needs to be dehydrated to a controlled water content in order to avoid gas hydrates and to minimize corrosion.

1.3 RESEARCH OBJECTIVES

1.3.1 To investigate the effective parameters on Natural Gas Dehydration Plant.

1.3.2 To evaluate the optimum parameters of triethylene glycol dehydration unit by using Aspen HYSYS.

1.4 SCOPE OF STUDY

The scope of study was to study the optimum parameters of triethylene glycol, which were number of theoretical stages, pressure, and gas flow rate. Optimization of parameters will be made based on the performance of drying agent which is triethylene glycol. Absorption dehydration involves the use of a triethylene glycol to removal water vapor from the gas.

1.5 SIGNIFICANCE OF STUDY

Dehydration to the gas will be subjected to prevent hydrate formation and corrosion from condensed water. The latter consideration is especially important in gas streams containing CO_2 or H_2S where the acid gas components will form an acid with the condensed water.

Natural gases either from natural production or storage reservoirs contain water, which condense and form solid gas hydrates to block pipeline flow and especially control systems. Natural gas in transit to market should be dehydrated to a controlled water content to avoid hydrate as well as to minimize the corrosion problems.

CHAPTER 2

LITERATURE REVIEW

2.0 LITERATURE REVIEW

2.1 INTRODUCTION

For hundreds of years, natural gas has been known as a very useful substance. The Chinese discovered a very long time ago that the energy in natural gas could be harnessed, and used to heat water. In the early days of the natural gas industry, the gas was mainly used to light streetlamps, and the occasional house. However, with much improved distribution channels and technological advancements, natural gas is being used in ways never thought possible. According to the Energy Information Administration, energy from natural gas accounts for 23% of total energy consumed in the United States, making it a vital component of the nation's energy supply. Natural gas is used across all sectors, in varying amounts. The industrial sector accounts for the greatest proportion of natural gas use in the United States, with the residential sector consuming the second greatest quantity of natural gas.

However, natural gases either from natural production or storage reservoirs contain water, which condense and form solid gas hydrates to block pipeline flow and

especially control systems. Natural gas in transit to market should be dehydrated to a controlled water content to avoid hydrate as well as to minimize the corrosion problems.

2.2 INTRODUCTION OF DEHYDRATION

Natural gas contains many contaminants which the most common impurity is water. Most natural gas will be near water saturation at the temperature and pressure of production. Dehydration of natural gas is the removal of the water that is associated with natural gases in vapor form. The natural gas industry has recognized that dehydration is necessary to ensure smooth operation of gas transmission lines. Removal of water from the gas stream reduces the potential for corrosion, gas hydrates formation and freezing in the pipeline. Unless gases are dehydrated, liquid water may condense in pipelines and accumulate at low points along the line, reducing its flow capacity. Water is removed to meet a water dew point requirement of a sale gas contract specification range from 32.8 to 117 kg/10^6 std m^3(Gandhidasan P. et al., 2001). Several methods have been developed to dehydrate gases on an industrial scale.

2.3 THEORY OF ABSORPTION

Absorption is a physical or chemical process in which atoms, molecules, or ions enter some bulk phase, means gas, liquid or solid material. This is a different process from adsorption, since molecules undergoing absorption are taken up by the volume, not by the surface. (McMurry,J & McDonald,A , 2003). Absorption dehydration involves the use of liquid desiccant to remove water vapor from the gas. The liquid that is most desirable to use for commercial dehydration purposes should possess high absorption efficiency, and easy and economic regeneration. It should be non-corrosive and non-toxic, no operation problems when used in high concentration, no interaction with the hydrocarbon portion of the gas, and no contamination by acid gases. There are numbers of liquids that can be used to absorb water from natural gases such as calcium chloride, lithium chloride, and glycols.

Triethylene glycol (2-2'-(1,2-ethanediylbis(oxy))ethanol) is a stable, non-corrosive chemical with high flash point. It is a straight-chain dihydric alcohol aliphatic compound terminated on both ends by a hydroxyl group. It is a clear, practically colorless and odorless, hygroscopic liquid at room temperature. It is used as a dehydrating agent for natural gas; a solvent and lubricant in textile dyeing and printing; a plasticizer, a raw material for the production of polyester resins and polyols; a humectants; a constituent of hydraulic fluids; a selective solvent for aromatics (Huntsman, 2007). The structure of triethylene glycol is shown as follow:

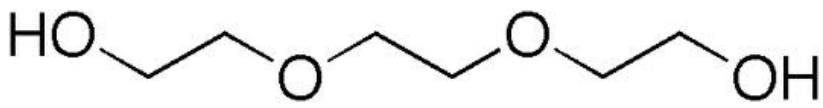

Figure 2.1: Straight-chain dihydric alcohol aliphatic compound - TEG

2.4 PREVIOUS STUDY ON LIQUID DESICCANT DEHYDRATION

As said by Honerkamp et al. (1983), there are a variety of ways for separating water from gas, but the method most commonly employed in the petroleum industry is the use of glycol or other liquid desiccant dehydrators. Glycol readily mixes with water and has a lower vapor pressure than water. Thus, it is well known to pass wet gas into contact with glycol wherein the water in the gas is absorbed by the glycol. The gas is then passed in an upward column wherein the glycol/water mixture is then heated to drive off the water, the dry or anhydrous glycol then being recirculated to contact wet gas in a continuous process so that water is extracted from a gas stream.

According to Smith,R.S. (1996), liquid desiccant system are relatively simple to operate and easy to maintain. However, it typically unable to produce treated gases with extremely low level of moisture. Solid desiccant systems are often used to provide gas with very low levels of moisture; however these plants can be more complex and expensive to operate than liquid desiccant systems. They also present a higher risk of downstream damage by failure of automatic regeneration switching valves. So, there is

a continuing need for a relatively simple liquid desiccant gas dehydration system that produces gas with the low moisture content normally associated with solid desiccant systems.

As stated by Gandhidasan,P et al (2001), the glycols have proved to be the most effective liquid desiccants in current use since they have high hygroscopicity, low vapor pressure, high boiling points and low solubility in and of natural gas. Triethylene Glycol has gained nearly universal acceptance as the most cost effective of the glycols due to superior dew pint depression, operating cost and operation reliability. However, there are several operating problems with glycol dehydrators. Suspended foreign matter may contaminate glycol solution. Overheating may produce both low and high boiling decomposition products. Resultant sludge may collect on heating surfaces and causing loss in efficiency. High concentrated glycol solutions tend to become viscous at low temperature and therefore hard to pump. Glycol lines may solidify completely at low temperature when the plant is not operating. Furthermore, there are substantial environmental problems due to fugitive emission, soil contamination, and fluid disposal problems.

From Natural Gas Transmission and Processing Handbook (2006), the amount of water to be removed in a TEG system is calculated from the gas flow rate, the water content of incoming gas, and the desired water content of outgoing gas. By assuming the inlet gas is saturated with water, the water removal rate can be determined as $W_r = \frac{Q_G(W_i - W_o)}{24}$, where W_r is water removed, lb/hr; W_i is water content of inlet gas, lb/MMscf; W_o is water content of outlet gas, lb/MMscf; and Q_G gas flow rate, MMscfd.

The glycol circulation rate is determined on the basis of the amount of water to be removed and is usually between 2 and 6 gallons of TEG per pound of water removed, with 3 gallons TEG/lb water being typical. Higher circulation rates provide little additional dehydration while increasing reboiler fuel and pumping requirements. Problems can arise if the TEG recirculation rate is too low. Therefore, a certain amount of overcirculation is desired. An excessive circulation rate may overload the reboiler and prevent good glycol regeneration. The heat required by the reboiler is directly proportional to the circulation rate. So, an increase in circulation rate may decrease the

reboiler temperature, decreasing lean glycol concentration, and decrease the amount of water that is removed by the glycol from the gas. To lower the dew point of the gas, the circulation rate can be increased and the reboiler temperature must remain constant (Saeid M. et. al., 2006).

From Saeid M. et. al (2006), usually the glycol absorber contains 6-12 trays that provide an adequate contact area between the gas and the glycol. With increasing number of trays, the greater the dew point depression for a constant glycol circulation rate and lean glycol concentration. On the contrary, specifying more trays with the same TEG concentration, a lower circulation rate is required. By specifying more trays, fuel savings can be realized because the heat duty of the reboiler is directly related to the glycol circulation rate. Also, calculated tray efficiency values depend on the TEG/water equilibrium data used.

Since absorption is an exothermic process, increasing input TEG temperature decreases water absorption rate. In real dehydration plants, temperature of TEG entering the absorption tower is kept at 5-6˚C more than entering gas temperature (Kasiri N. and Hormozdi Sh., 2005). Water absorption rate as a function of TEG temperature is represented in the following figure:

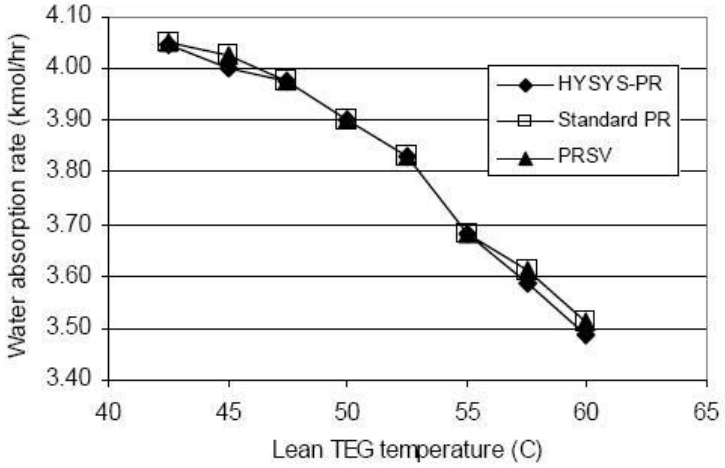

Figure 2.2: Effect of TEG temperature on water absorption rate

Increasing number of equilibrium stages increases water absorption rate as well as manufacture and maintenance costs (Kasiri N. and Hormozdi Sh., 2005). As number of stages increases, glycol circulation rate decreases. Percentage of water removal as a function of number of equilibrium stages in absorber is represented in the following figure:

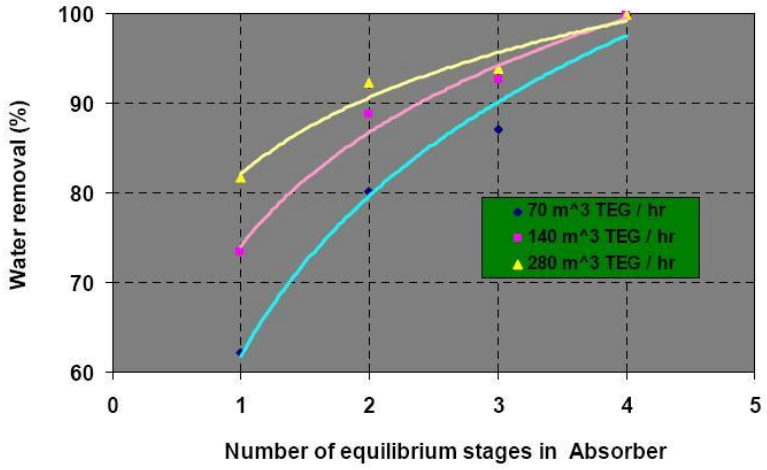

Figure 2.3: Effect of number of equilibrium stages in contactor on percentage of water removal

At a constant temperature, the water content of the inlet gas decreases with an increasing pressure. Less water is removed if the gas is dehydrated at a higher pressure (Mohamadbeigy Kh., 2008). At lower pressure, wall thickness required is lesser. Therefore, an economic trade-off exists between operating pressure and contactor cost.

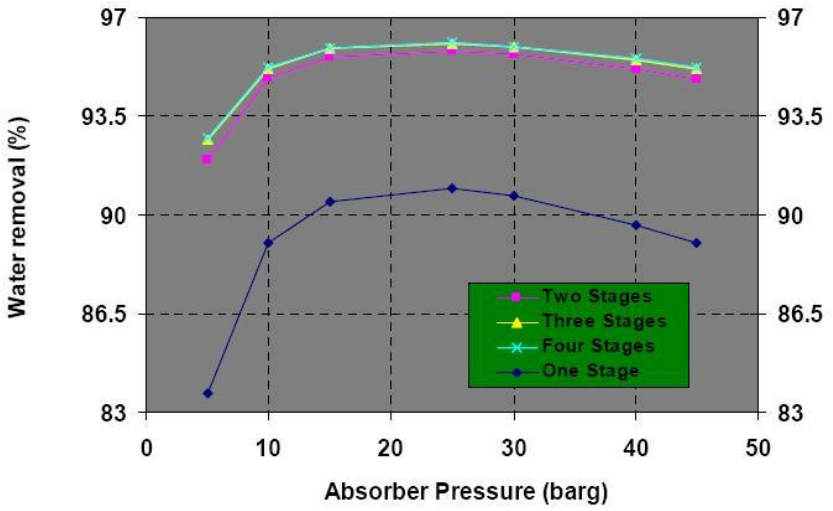

Figure 2.4: Effect of pressure in contactor on the water content of gas stream

However, there are also some operating problems associated with the absorber, which are insufficient dehydration, foaming, and hydrocarbon solubility in glycol. From Saeid M. et. al.(2006), lean glycol purity plays a main role in the rate of water removal. A minimum lean glycol concentration is needed to achieve a specified dew point depression. Higher water concentrations in the lean glycol results in poor dehydration. Temperature of the inlet gas dictates the amount of water fed into the unit. A lower inlet gas temperature will require less water to be removed by the glycol. Lean glycol temperature at the top of the absorber will affect the water partial pressure at the top stage, where high TEG temperature may cause high moisture content of the outlet gas. Reboiler temperature can therefore be increased up to 400^{o}F above which glycol degradation starts.

From Handbook of Natural Gas Transmission and Processing (2006), due to poor heat transfer, lean glycol results in too warm temperature and poor dehydration and insufficient dew point depression can be resulted. Also, glycol vaporization losses to the product gas may be higher with increased lean glycol temperature. Poor heat transfer and the resulting high lean glycol temperature may be caused by fouled heat exchangers, undersized heat exchangers, or over circulation. Exchangers may be fouled by deposits such as salt, solids, coke, or gum. In the case of undersized exchangers, additional heat exchangers may be required.

From Saeid M. et. al. (2006), pump reliability is enhances by limiting the lean glycol temperature from 180^{o}F to 200^{o}F and ensuring good filtration. Pump wear, leakage, and failures increase if the glycol becomes dirty or hot. It is possible that the seals on the glycol balance pumps wear out and contaminate the lean glycol by the rich glycol. This increases the water content of the lean glycol and may cause the gas no longer to be dried to pipeline specifications. Excessively high glycol circulation rates can lead to many problems. If the unit is over circulating the glycol, the lean glycol may have insufficient heat exchangers to be cooled properly, and the resulting hot lean glycol may not achieve the desired water removal rate. A high circulation rate may not allow adequate residence time in the phase separator for the hydrocarbons to be removed, which may lead to hydrocarbon deposits, glycol losses, foaming, and emissions. Excessive glycol circulation rates can also result in increased sensible heat requirements in the reboiler. Also, as emissions are proportional to the circulation rate, over circulation results in greater VOCs emissions. However, under circulating the glycol provides an insufficient quantity of glycol in the absorber for the quantity of water to be removed and results in wet sales gas.

2.5 ABSORPTION MODEL DESCRIPTION

There are four sets of equations, mass balance, equilibrium relations, sum of mole fractions of each phase and heat balance are used to describe tray columns treatment. Material balance of component *i* on tray *j*, for liquid phase is as follows (Kasiri.N, and Hormozdi.Sh., 2005) :

$$L_j x_{i,j} - L_{j+1} x_{j+1} - F^{l}{}_{i,j} = 0 \qquad [1]$$

where L is liquid molar flow rate, x is mole fraction in liquid phase, F is feed molar flow rate and the superscript l refers to liquid phase. If the impact of entrainment factor in vapor phase is considered, the following equation will be obtained:

$$(1 + E^{l}_{j})\, L_j x_{i,j} - L_{j+1} x_{i,j+1} - E^{l}{}_{j-1} L_{j-1} x_{I,j-1} - F^{l}{}_{i,j} = 0 \qquad [2]$$

Equilibrium relation for component *i* at tray *j* is given by:

$$K_{i,j} = y_{i,j} / x_{i,j} \quad [3]$$

where K is equilibrium constant. Sum of mole fraction of each phase are shown as follows:

$$\sum_{i=1}^{N} y_{i,j} = 1 \, , \sum_{i=1}^{N} x_{i,j} = 1 \quad [4]$$

Energy balance equation is as follows:

$$L_{j+1} H_{Lj+1} + V_{j-1} H_{Vj-1} + F_j H_{Fj} - L_j H_{Lj} - V_j H_{Vj} - Q_j = 0 \quad [5]$$

Real enthalpy of components is calculated by combination of ideal gas enthalpy and residual enthalpy of gases and liquids. Ideal gas enthalpy is evaluated by:

$$H^{ig}_i = a' + b'T + c'T^2 + d'T^3 + e'T^4 + f'T^5 \quad [6]$$

where *a',b',c',d',e',*and *f'* could be found in literature (Prausnitz, J.M., 1999). General form of gas and liquid residual enthalpy are as follows:

$$\frac{H - H^{ig}}{RT} = \frac{1}{RT} \int_0^P [\forall - T(\frac{\partial \forall}{\partial T})_P] dP \quad [7]$$

$$(\frac{\partial Ln f_i^l}{\partial T})_{P,x} = -\frac{\bar{H}_i - H_i^+}{RT^2} \quad [8]$$

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